Process for Revising the MRP Inspection Plan for Upper Head Penetrations

Craig Harrington, TXU
MRP Alloy 600/82/182 ITG
RV Head Working Group Chairman

NRC-MRP Meeting
June 12, 2003

Topics

- Revision to MRP-75
  - Key changes from MRP-75
  - Combination Baseline Inspections
  - Safety Assessment Process Overview
  - Failure Modes and Effects Analysis
  - Main Evaluations
    - Nozzle Ejection
    - Head Wastage
  - Supporting Evaluations
    - Crack Growth Rates
    - Stress Intensity Factors
- Schedule for Issuing Revised Inspection Plan and Safety Assessment Report

Key Changes from MRP-75

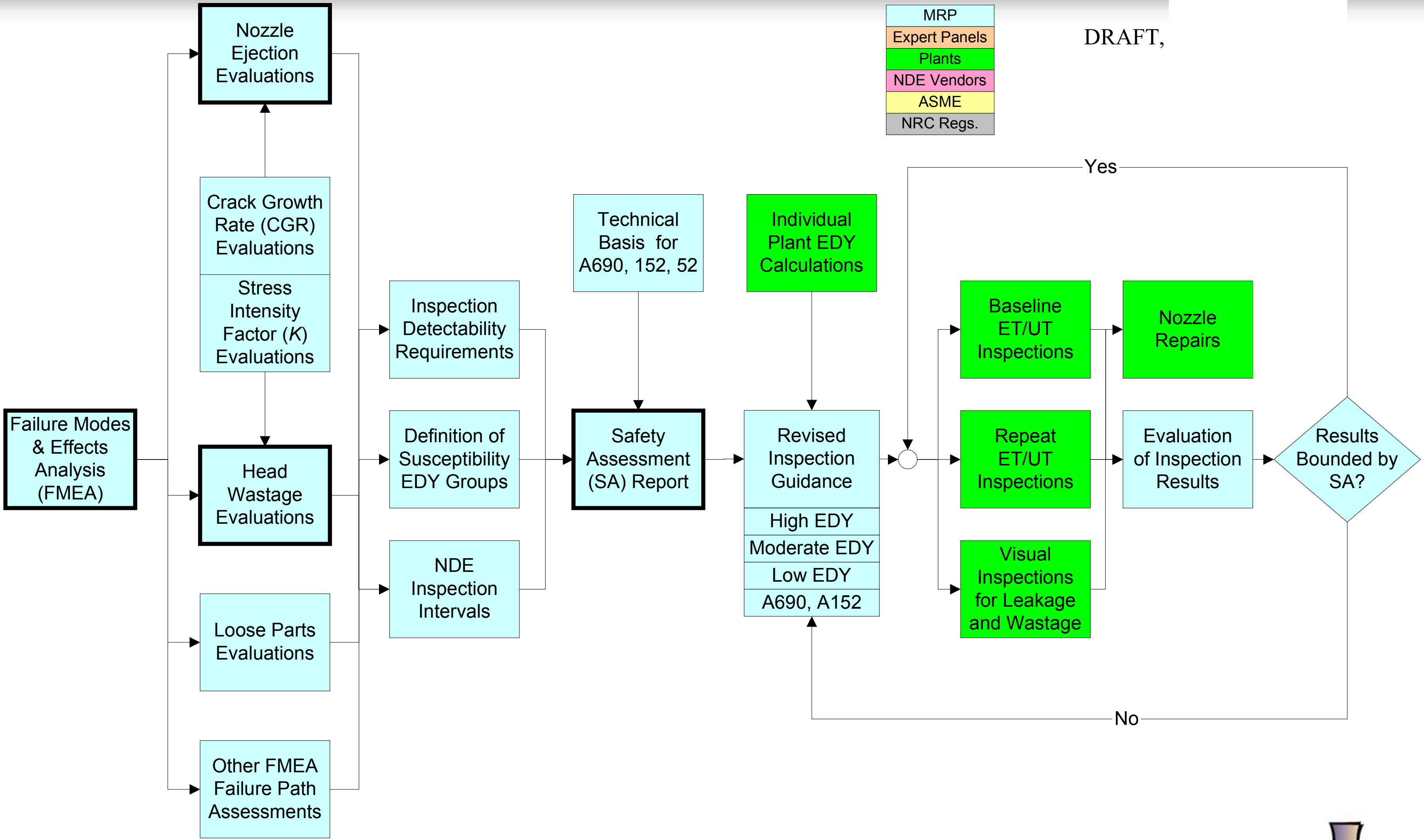
- Implementation of baseline exams employing a combination of techniques
- Proactive rather than reactive approach

Combination Baseline Inspections

- MRP released a letter (November, 2002) to the industry recommending a transition to combination baseline inspections
  - Incorporated fall inspection results
  - Revised MRP-75 reliance on visual inspection
  - Recommended three types of combination inspections
    - UT/BMV, UT/ET, or ET/ET
  - Based the timing of the baseline inspection on susceptibility

- NRC issued order with similar requirements

Overall Process Flowchart



EPRI

Failure Modes and Effects Analysis: Introduction

- FMEA is a technique of TQM (Total Quality Management) to ensure product reliability
- Typically, a table of the following characteristics of the possible failure modes is prepared:
  - Cause
  - Effect (consequence)
  - Detectability
  - Frequency of Occurrence
- Relationships among the failure modes are illustrated using a block diagram
- FMEA is a tool that helps anticipate new failure modes

Failure Modes and Effects Analysis: Application to RVH Nozzles

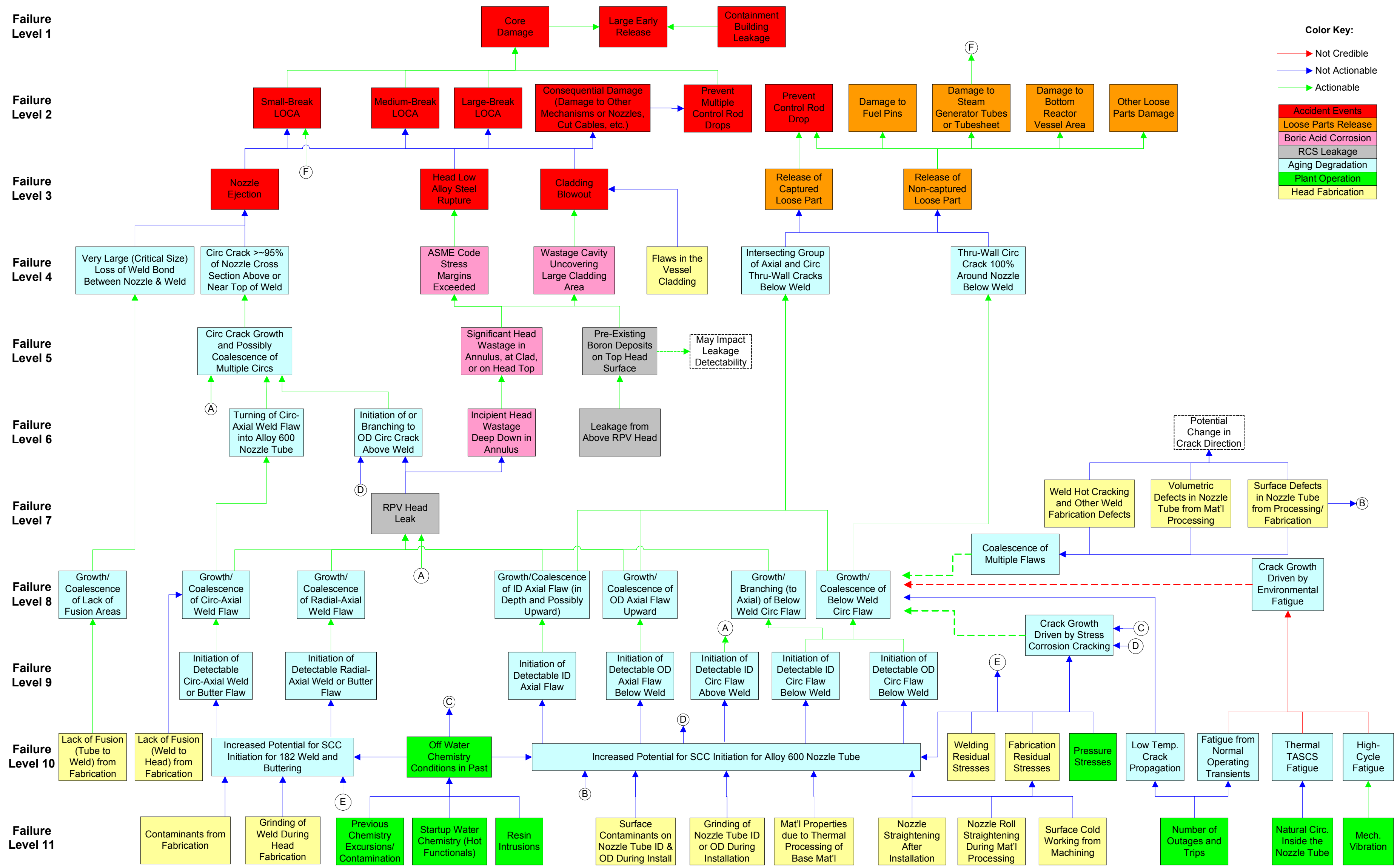
- For RVH penetrations, there are three principal failure modes:
  - Nozzle Ejection Due to Net Section Collapse
  - Cladding Blowout Due to Wastage
  - RCS Damage Due to Loose Parts Generation
- There are several levels in the failure process for these modes:
  - PWSCC initiation (nozzle ID, nozzle OD below weld, weld surface)
  - PWSCC growth (axial and circ in nozzle, axial-radial and circ-axial in weld; weld to nozzle and nozzle to weld; turn from axial to circ)
  - Leakage to annulus (new crack initiation and low-alloy steel wastage)
  - Growth to allowable size / wastage until code allowable stresses are reached
  - Growth to net section collapse or loose parts release / wastage to cladding blowout
  - LOCA and possible consequential damage / loose parts damage
  - Effect on core damage frequency (CDF)

Failure Modes and Effects Analysis: Classification of Failure Conditions

- Each failure condition will be classified as:
  - Not credible,
  - Not actionable, or
  - Actionable
- A classification as “not credible” will require a strong technical argument and thorough documentation with a high threshold
- A classification as “not actionable” requires that adequate protection be provided at a higher level in the failure process
- Conditions classified as “actionable” will be inputs to the probabilistic and deterministic evaluations and will ultimately shape the detectability requirements specified in the inspection plan

MRP Failure Modes and Effects Analysis for Reactor Vessel Heads

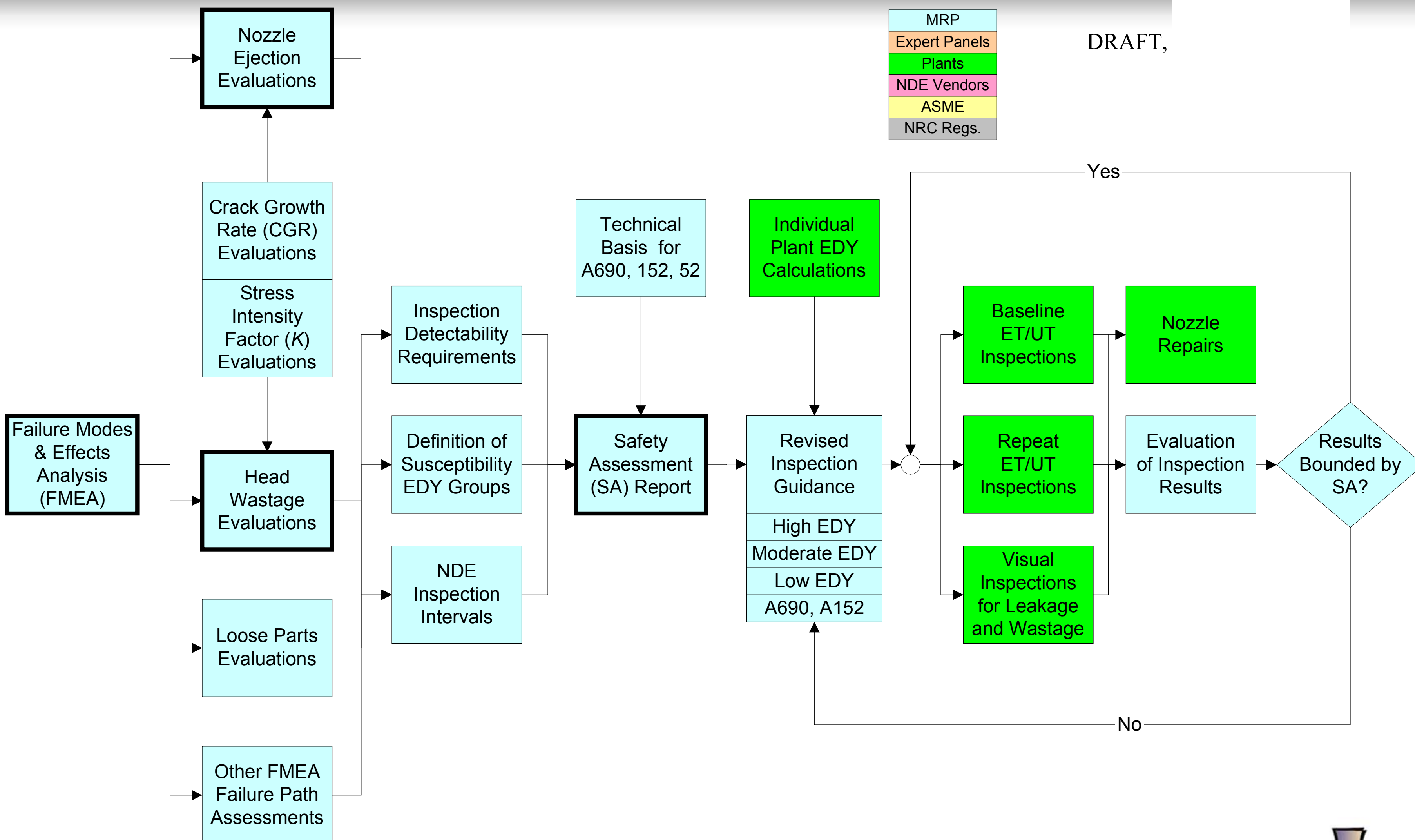
FINAL for Working Group Approval, May 21, 2003



Failure Modes and Effects Analysis: Frequency of Occurrence

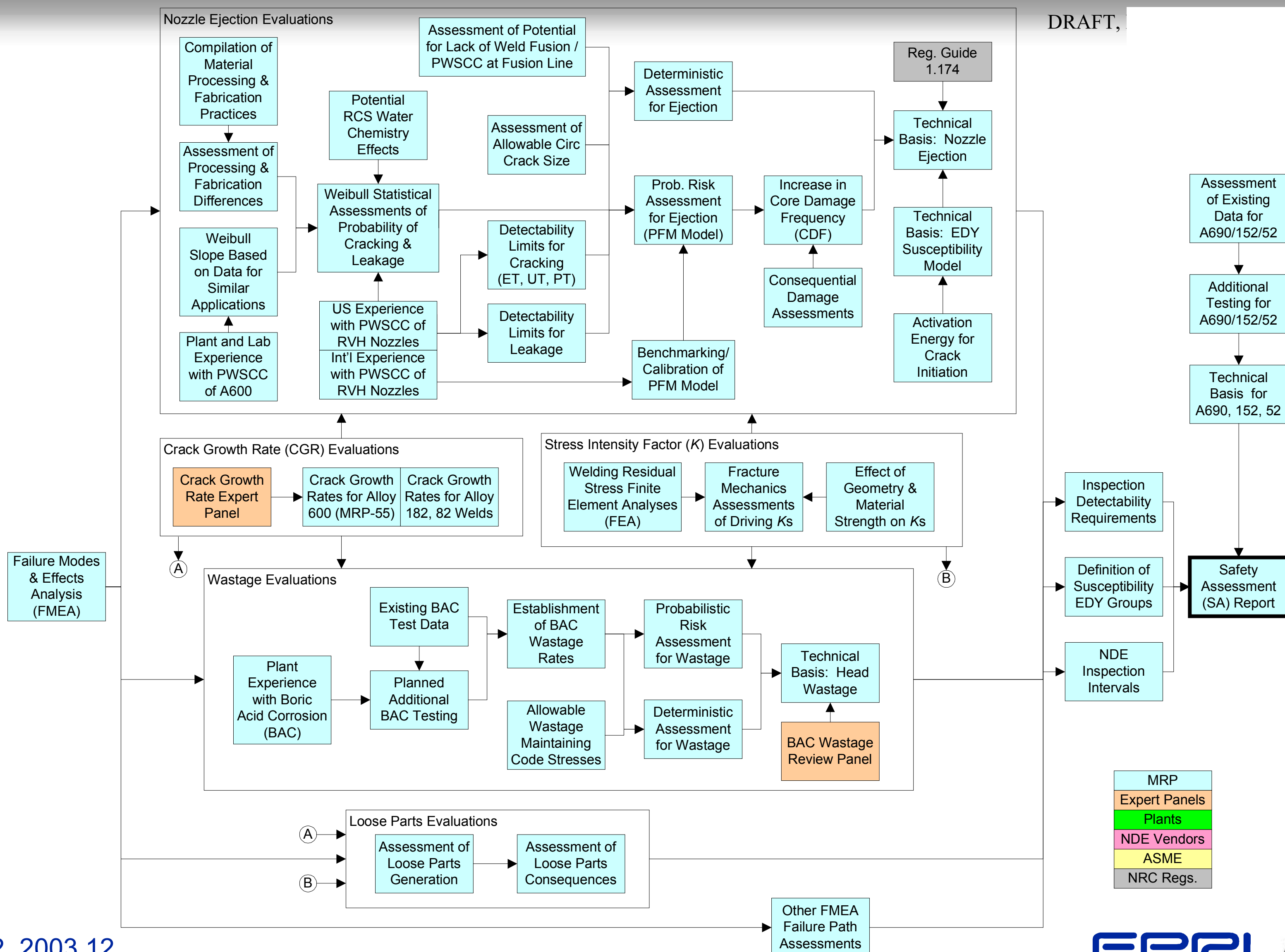
- Sources of data for determining frequency of occurrence
  - Weibull reference curves based on the latest inspection results (next presentation)
  - Crack growth rates based on MRP-55 (next presentation)
  - Stress intensity factor calculations (next presentation)
  - Boric Acid Corrosion Testing (previous presentation)
  - Existing LOCA analyses
  - Consequential damage assessments
  - Loose parts damage assessments

Overall Process Flowchart

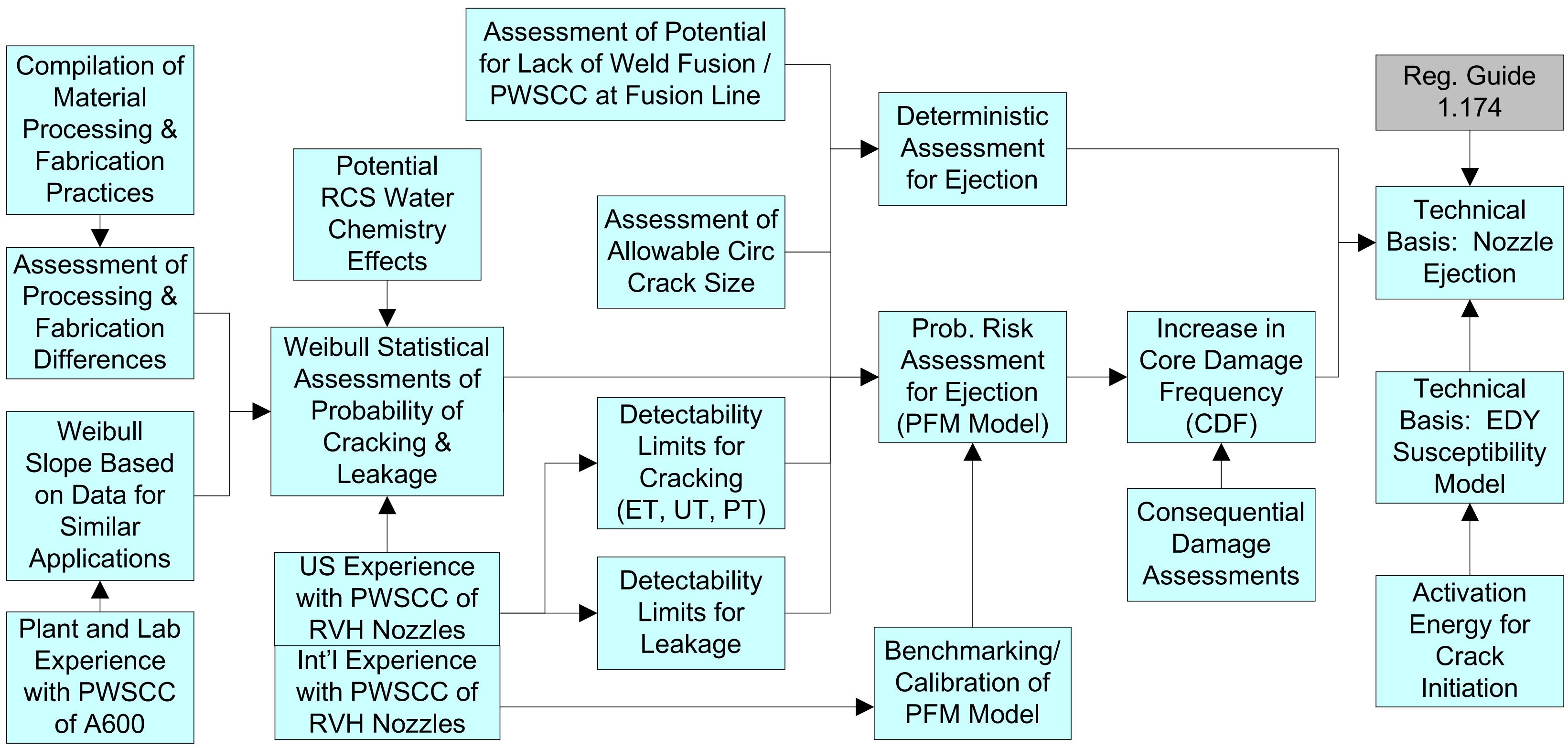


Safety Assessment Process

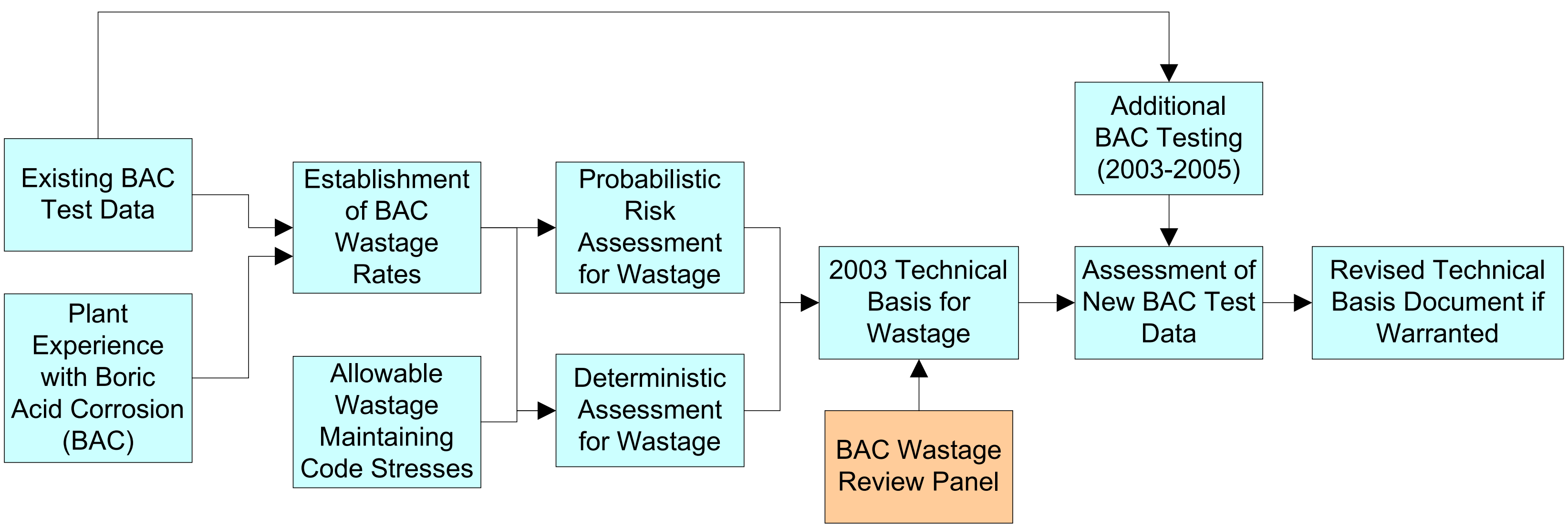
DRAFT,



Main Evaluations: Nozzle Ejection



Main Evaluations: Head Wastage



Supporting Evaluations: Crack Growth Rates

- The MRP report addressing the crack growth rates (CGRs) of Alloy 600 base metal (MRP-55) was formally submitted to the NRC in September 2002
- The NRC issued a new flaw evaluation guideline (letter to NEI on 4/11/2003) which used the MRP-55 crack growth rate
- PWSCC CGR data for 182/82 contains data from the US and results generated overseas (France, Sweden, Japan)
- A report addressing the weld metal will be produced after data is evaluated

Supporting Evaluations: Stress Intensity Factors

- Stress intensity factor calculations have been completed for several CRDM nozzle geometries
- Comparison with the results produced by the NRC contractor have shown good agreement for same crack geometries
- More conservative stress intensity factors used in current model to address envelope stress distribution above J-groove weld
- Additional work is being performed to evaluate the effect of weld geometry on the stress intensity factors
- The stress intensity factors are a secondary influence behind the crack growth rates on the probability of nozzle ejection

Safety Assessment Process: Key Points

- The MRP approach has transitioned to ensuring safety through “combination” inspections at all plants with:
  - The timing for the baseline inspection and the re-inspection interval based on the technical evaluations
  - More frequent bare metal visual (BMV) inspections providing backup to the program of periodic combination inspections

Safety Assessment Process: Key Points – cont'd

- Proactive identification of possible failure modes
  - Employs a structured approach – FMEA
    - Anticipate possibility of failure paths not yet observed in field
    - Direct subsequent technical evaluations in SA
    - Identify inspection detectability requirements
    - Ensure robust defense for all credible failure paths

Safety Assessment Process: Key Points – cont'd

- Calculations show that non-visual inspections do not have to be performed every refueling outage to ensure safety across the fleet
  - Extremely low probability of nozzle ejection and significant wastage
  - Extremely small consequential increase in core damage frequency (<10^{-6} per reactor year), consistent with NRC Reg. Guide 1.174

Safety Assessment Process: Deliverables

- A comprehensive safety assessment (SA) report will form the basis for a revised MRP inspection plan
  - The Safety Assessment report will:
    - Begin with FMEA
    - Include the analysis tools previously developed and described in MRP-75
    - As appropriate, the SA report will reference other reports (e.g., the MRP report on crack growth rates of Alloy 600—MRP-55)
    - Demonstrate safety of operation based on knowledge of hardware condition
- The revised MRP inspection plan will be formed on the basis of the Safety Assessment report
  - Defines inspection requirements necessary to establish hardware condition relative to SA requirements

Schedule Considerations

- Some calculations remain to be revised and extended, but much of the material to be incorporated into the SA report has already been completed in support of MRP-75

- Data developed subsequent to the initial release of the SA report will be evaluated for consistency with the SA evaluations once such data become available
  - BAC Testing & NA2 Destructive Exam results

- Final submittal expected Spring 2004
  - The MRP will be prepared to discuss a draft of the SA and the revised inspection plan in Fall 2003
  - In the meantime, technical discussions with the NRC staff will continue